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Heavy Metal Accumulations of 4 Species of Anseriformes in Korea

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Abstract: The study figured out the tendency of distribution of lead (Pb) and cadmium (Cd), and compared and examined the heavy metal accumulations among species by measuring the heave metal accumulations in major organs (liver, muscle, kidney and bones) targeting 31 birds in 4 species(*Cygnus cygnus, Anser albifrons, Aix galericulata* and *Anas formosa*) of Anseriformes. Concentration of lead (Pb) in tissues was generally high in kidney (1.54 μg/wet g) or bones (5.94 μg/wet g), and concentration of cadmium (Cd) was generally high in kidney (0.474 μg/wet g) and low in muscles (0.019 μg/wet g). As shown above, there was no bird containing more than the standard amount of cadmium (Cd) among Anseriformes, but the study confirmed from 3 species (*Cygnus cygnus, Anser albifrons, Aix galericulata and Anas formosa*) containing lead at exposed levels and at poisoned levels. It is judged that the study result will be used as a comparing material for studies monitoring heavy metal of Anseriformes, a winter bird and a bio-indicator in an aquatic ecosystem and a basic material for reasonable environmental policy of lead shots and lead sinker in the future.

Keywords: Anseriformes, Lead (Pb), Cadmium (Cd), bio-indicator, Lead poisoning

Introduction

Heavy metals are not purified by the sanitation facilities or the nature's self-purification capacity unlike other pollutants, and their amount increases with the course of time in the natural world, causing biological magnification which is accumulated in a specific organism (Phillip, 1980). Heavy metals mean a metallic element with 4.0 or more specific gravity, and cadmium (Cd), mercury (Hg), lead (Pb), and antimony (Sb) are metals unnecessary in the living body, and they are not decomposed but accumulated in the body, causing harmful effects. Also, when they are ionized, they are easy to react with biogenic substances such as protein or nucleic acid, and have significant influences on 3-dimensional structure of protein or active revelation of enzyme. In addition, heavy metals are sometimes displaced with the necessary metals located at the center of vitality of metalloenzymes. In order to directly or indirectly evaluate the degree of exposure to heavy-metal contamination and the level of hazard, it is necessary to conduct biological monitoring using biological indicator species (Furness and Greenwood, 1993). Birds which are located in higher trophic levels in the ecosystem and can provide information on the range of contamination in the whole food chains are widely used for monitoring heavy-metal contamination or as an indicator species (Blus *et al*., 1993). Birds are known for being influenced by the distribution and accumulation of heavy metals in the body due to complex physiological functions such as breeding, growth, molt and spawning and various factors such as seasonal migration, types of food and the level of contamination in their food field (Hutton. 1981; Honda *et al*., 1985; Honda *et al*., 1986a, b, c). They show a close correlation between each organ and between elements in the process to absorb and redistribute heavy metals in the body. In such a process, they show difference in the level of distribution and accumulation of heavy metals in the body (Burger and Gochfeld, 2000). Also, as birds live in various kinds of environment including deserts, forests, grasslands, rivers, lakes and oceans, have various kinds of food habits including herbivorous, insectivorous, carnivorous, ichthyophages and omnivorous, and have different lifespans from several years to several decades, they have a feature to accumulate high-concentration of various pollutants emitted in the environment in their body (Lee, 1995).

A study on heavy-metal accumulation in Anseriformes is

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Table 1. List of bird analyzed

Species	*N	Sampling date	Sampling site	Cause of death (n)
Cygnus cygnus	5	00.12.~02.12.	Jeollanam-do Yeosu-si Chungcheongnam-do Dangjin-gun Chungcheongnam-do Taean-gun Chungcheongnam-do Seosan-si	Unknown (3) Exhaustion (1) Shot (1)
Anser albifrons	10	00.10.~04.03	Chungcheongnam-do Seosan-si Gyeonggi-do Yeoju-gun, Paju-si Gangwon-do Cheorwon-gun Incheon Ganghwa-gun Jeollabuk-do Gunsan-si	Cholera (1) Exhaustion (1) Poison (8)
Aix galericulata	12	01.03.	Gyeongsangnam-do Sacheon-si	Poison
Anas formosa	4	00.10	Chungcheongnam-do Seosan-si	Cholera
Total	31			

*N: Number of individual

considered as an appropriate bio-indicator toward heavy-metal pollutants in water environment (Scheuhammer, 1989; Congiu *et al*., 2000). As for the study on heavy-metal accumulation in Anseriformes in Korea, there is a study on the difference among species in the accumulating level of heavy metals in birds' organs (Lee, 1995), examining several species belonging to Anseriformes, but it is not sufficient domestically.

Therefore, this study was conducted in order to provide the basic materials for monitoring environmental pollution by figuring out the tendency of distribution of elements through the measurement of the concentration of heavy metals in birds' body targeting 4 species of Anseriformes including *Cygnus cygnus, Anser albifrons, Aix galericulata* and *Anas Formosa* and by comparing and examining the concentration of heavy metals between species.

Materials and Methods

The study subjects are 31 individuals of 4 species collected by being supported by the Korean Association for Bird Protection from 2000 to 2004 (Table 1). In order to analyze heavy metals in the body, collected birds were dissected for measuring the weight of each part, 1-5 g of specimen was completely disassembled in the Kjeldahl digestion apparatus using sulfuric acid, nitric acid and perchloric acid, and the dissolved solution was diluted into 100ml solution. The dissolved solution was enriched and extracted in DDTC-MIBK method, and lead (Pb) and cadmium (Cd) were analyzed using an atomic absorption spectrometer (Shimadzu AA-6400, Co. Ltd, Japan) (Lee *et al*., 1989). Detection limit was 0.1 μg/wet g or less for lead (Pb) and 0.01 μg/wet g or less for cadmium (Cd). Statistical analysis of data was conducted using SPSS program (version 10.0, SPSS), and as the concentration of heavy metals was abnormal distribution, Kruskal-Wallis test was used for comparing concentration of each element between species through a non-parametric test for data analysis (Alessandra *et al*, 2005).

Results

Lead (Pb)

The concentration of lead (Pb) was generally high in kidney or bones. Lead (Pb) in liver was the highest in *Aix galericulata* (3.18 μg/wet g), and the lowest in *Cygnus cygnus* (0.39 μg/wet g) (x^2=46.4, p<0.05). As for muscles, it was the highest in *Anser albifrons* (2.60 μg/wet g) and the lowest in *Aix galericulata* (0.48 μg/wet g) (x^2=46.0, p<0.05). In kidney, it was the highest in *Aix galericulata* (2.40 μg/wet g) and the lowest in *Cygnus cygnus* (0.69 μg/wet g) (x^2=46.8, p<0.05). In bones, *Anser albifrons* showed the highest concentration by about 20 times (20.7 μg/wet g) compared with other species, and *Cygnus cygnus* showed the lowest concentration (0.59 μg/wet g) (x^2=55.3, p<0.05) (Table 2).

Table 2. Lead (Pb) concentration (μg/wet g) in tissues of 4 bird species from Korea

Family/species	N		Liver	Muscle	Kidney	Bone
Cygnus cygnus	5	Median Range	0.56 0.03~28.9	0.55 0.11~2.81	0.69 0.27~17.7	0.59 0.04~23.2
Anser albifrons	10	Median Range	0.61 0.08~34.4	0.63 0.03~7.85	0.93 0.01~95.2	1.17 0.16~24.7
Aix galericulata	12	Median Range	3.18 2.11~303	0.48 0.22~0.94	2.40 1.50~4.41	1.30 0.90~1.95
Anas formosa	4	Median Range	0.88 0.78~4.02	2.60 0.60~5.61	2.12 0.60~10.9	20.7 8.79~147

Table 3. Cadmium (Cd) concentration (μg/wet g) in tissues of 4 bird species from Korea

Family/species	N		Liver	Muscle	Kidney	Bone
Cygnus cygnus	5	Median Range	0.138 0.015~1.134	0.008 0.0020.014	0.162 0.077~2.651	0.026 0.004~0.029
Anser albifrons	10	Median Range	0.283 0.042~0.483	0.019 ND~0.078	1.100 0.081~3.244	0.029 ND~0.083
Aix galericulata	12	Median Range	0.140 ND0.319	0.037 0.0140.081	0.604 0.3222.304	0.045 0.0200.062
Anas formosa	4	Median Range	0.021 0.0070.034	0.012 0.007~0.033	0.031 0.002~0.258	0.154 0.0420.561

ND: not detected.

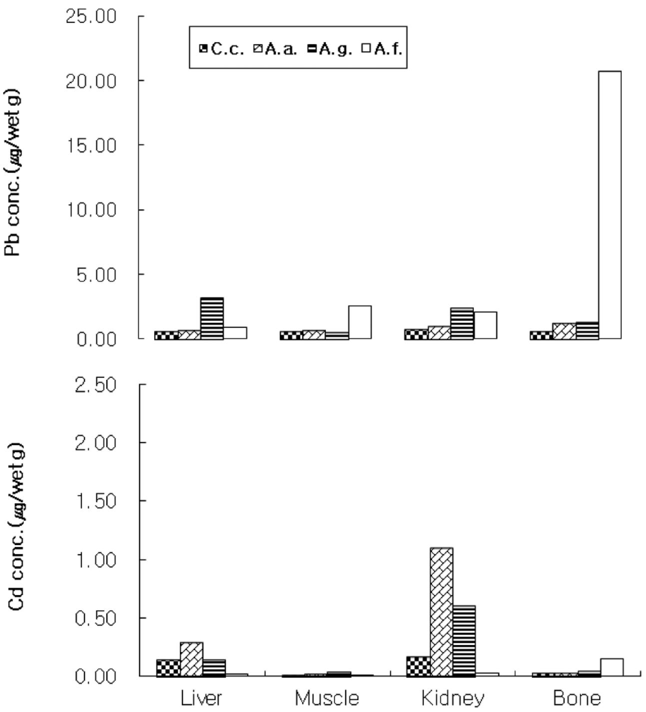

Fig. 1. Contamination elements distribution in tissue of each species (***C.c.***: *Cygnus cygnus*, ***A.a.***: *Anser albifrons*, ***A.g.***: *Aix galericulata*, ***A.f.***: *Anas formosa*)

Cadmium (Cd)

Concentration of cadmium (Cd) in organs was generally high in kidney and low in muscles. In liver, concentration of cadmium (Cd) was the highest in *Anser albifrons* (0.283 μg/wet g), and the lowest in *Anas formosa* (0.021 μg/wet g) (x^2=43.4, p<0.05). In muscles, the ranged from 0.008 μg/wet g (*Cygnus cygnus*) to 0.037 μg/wet g (*Anix galericulata*) (x^2=35.3, p<0.05). Concentration of cadmium (Cd) in kidney was the highest in *Anser albifrons* (1.100 μg/wet g) and the lowest in *Cygnus cygnus* (0.162 μg/wet g) (x^2=66.0, p<0.05). In bones, it was the highest in *Anas formosa* (0.154 μg/wet g) and the lowest in *Cygnus cygnus* (0.026 μg/wet g) (x^2=45.1, p<0.05) (Table 3).

Discussion

In this study, concentration of lead (Pb) was higher in kidney tissues or bones than in liver, and it is thought that it is related to a longer half-life of lead (Pb). It's because lead (Pb) in blood is combined with albumin or MT, plasma proteins, but as it delivered and stored in lived in combination mainly with albumin, and delivered to other organs including liver at rapid speed by combining loosely and reversibly, concentration in blood is maintained low (Kim and Kim, 1991). Also, it is known that a biological half-life of lead (Pb) is the longest in bones (Tsuchiya, 1986), and due to this, concentration increases in lead (Pb) relatively in a short term in liver and kidney, and concentration in bones increases relatively in a long term (Lee, 1995). Concentration of lead (Pb) in liver was 0.53 μg/wet g and 0.43 μg/wet g respectively in *Cygnus cygnus* and *Cygnus columbianus* in a wintering pond of Japan (Honda *et al*., 1990), showing similar concentration of *Cygnus cygnus* in this study. As for *Anatidae*, concentration of *Anas platyrhynchos* in the northwest area of Polland was 0.23~0.34 μg/wet g (Elzbieta *et al*., 2004), *Anas platyrhynchos* in Japan was 1.51 μg/wet g, *Anas crecca* was 0.37 μg/wet g (Lee, *et al*., 1987), *Aythya ferina* in Han river, Seoul was 0.32 μg/wet g, and *Aythya fuligula* was 1.53 μg/wet g (Lee, 1991), that of *Anatidae* in this study was higher by about twice.

In general, a living organism is exposed to high-concentration of lead (Pb), lead is first accumulated in liver, increasing the concentration in liver, but as for chronic exposure, the concentration increases in bones having a longer biological half-life (Freiberg and Nordberg, 1986). It is reported that high-concentration lead (Pb) disturbs vitality of essential enzymes for composing hemoglobin, leads to death by causing nervous and behavioral problems (Hui *et al*., 1998), and reduces the hatching rate and growth rate (Eisler, 1988). Clark and Scheuhammer (2003) clarified that the concentration of lead in liver lower than 6 μg/wet g is non-pollution, that between 6~30 μg/wet g is pollution and that higher than 30 μg/wet g is poisoning. Accordingly, this study judged the concentration of lead (Pb) in liver lower than 6 μg/wet g means non-pollution (background), that between 6~30 μg/wet g means pollution (exposed) and that higher than 30 μg/wet g means poisoning (poisoned). The pollution level of this study was 1 bird in *Aix galericulata* (303 μg/wet g), 1 bird in *Anser albifrons* (34.4 μg/wet g), and 1 bird in *Cygnus cygnus* (29.0 μg/wet g). Among them, it is judged that one bird in *Aix galericulata* showed high concentration of lead (Pb) accumulation by taking lead bullets or lead pendulum directly in their wintering place.

Cadmium (Cd) concentration tended to be higher in kidney than in liver. Generally, cadmium (Cd) is accumulated in a bird's body through the food chain, and cadmium (Cd) in the body is first accumulated in liver tissues, and delivered to several organs, and generally it is the highest in kidney tissues (Lee, 1996). As toxicity of Cadmium (Cd) due to chronic accumulation reveals in kidney, its impact is evaluated focusing on the concentration in kidney.

Concentration in *Cygnus cygnus* and *Cygnus columbianus* in wintering places of Japan is averagely 1.26 μg/wet g and 1.24 μg/wet g respectively (Honda *et al*., 1990), higher than that of *Cygnus* in this study (0.16 μg/wet g), and that of *Anser albifrons, Aix galericulata* and *Anas formosa* showed similar one with that of *Anas platyrhynchos* (2.58 μg/wet g) and *Anas crecca* (0.50 μg/wet g) (Lee *et al.,* 1987), *Aythya ferina* in Han River (0.36 μg/wet g), *Aythya fuligula* (0.88 μg/wet g), *Tadorna ferruginea* (0.87 μg/wet g) and *Anas acuta acuta* (0.98 μg/wet g) (Lee, 1991).

With the above results, birds in this study showed similar or low concentration compared with that of existing studies. Eisler (1985) estimated that about 10 μg/wet g of concentration in liver showed toxicity and had harmful influences. Most birds of this study showed less than standard levels of cadmium (Cd) toxicity.

As shown above, there was no bird showing high concentration beyond the standard level of Cadmium (Cd) among birds in *Anseriformes*, but as for lead (Pb), 3 birds from 3 species (*Anix galericulata, Anser albifrons* and *Cygnus cygnus*) showed the pollution level and poisoning level. Such lead pollution and lead poisoning is caused by lead bullets or lead pendulum which birds take with food in their feeding sites. It's because birds in *Anseriformes* take food with sands for mechanical dissolution of food in their gizzards, and at this time, they eat small-sized lead pendulum or lead bullets with sands (Blus *et al.* 1989; Pokras and Chafel 1992; Stone and Okoniewski, 2001). Also, secondary poisoning occurs when rapacious birds, higher predators most of which are globally endangered species eat the dead body of birds poisoned by lead (Lee, 2003). It will be necessary to conduct detailed demand research of lead bullets and lead pendulum and to enact reasonable environmental policies for regulating the use of lead in major wintering sites for migratory birds in order not to use them thoughtlessly. Also, the above results will be used as a comparing date for studies on monitoring heavy metals in *Anseriformes*, a bio-indicator in water ecosystem and a winter bird in the future.

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